ERIC Document Resume	See Instruction Sheet	DATE OF RESUME 6/4/65	DATE RECEIVED

A. PUBLICATION DATA

1. ERIC NUMBER	2. ORIGINATOR CONTROL NO(S).	3. IDENTIFICATION NO.	DO NOT WRITE IN SPACE BELOW
ED000692	8136		

4. AUTHOR(S): Gruber, Howard

5. TITLE OF DOCUMENT ABSTRACTED: Science as Thought: A Study of Nine Academic Year Institutes for the Training of Science Teachers, 1958-59

6. PUBLICATION TITLE: Univ. of Colo. Behavior Research Laboratory Report No. 16

7. EDITOR(S): N.A.

8. PLACE OF ORIGIN: ORG. Univ. of Colo. ST. Boulder, Colo. CITY, STATE

9. PUBLISHER OR SOURCE: Univ. of Colo.

10. VOL.	11. PAGES	12. MO./YR.	13. TOTAL PP.
N.A.	N.A.	May 61	28

TELE. EXT. INST/LOC CODE

MICROFILM COPY AVAILABLE: YES ☒ NO ☐

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TYPE OF REPORT: PROPOSAL ☐ IN-PROGRESS ☐ FINAL ☒ FOLLOW-UP ☐

OTHER ERIC REFERENCES:

ERIC SATELLITE CODE

B. INDEXING DATA

14. SUBJECT AREA

15. TYPE OF ENDEAVOR: case study

16. INDEXING TERMS (6-12)

case studies	science	evaluation		
higher edu.	teacher edu.	teaching methods		
professional edu.	mathematics			

17. ABSTRACT (MAX. 250 WORDS)

A study of institutes in which experienced teachers of high school science and mathematics were given advanced training. The major focus of the study was an attempt to evaluate the teachers' approach to science teaching at the end of the training year—whether they demonstrated any appreciable concern for teaching science as a way of thought or as a set of established facts and doctrines.

ERIC No.

18. SOURCE OF ABSTRACT

C. FUNDING DATA

19. SUPPORTING ORGANIZATION	20. DIVISION OR DEPT.	21. CONTRACT NO. / PROJECT NO.
	22. TOTAL COST OF PROJECT	
	23. DURATION OR PROJECT	U.S. Department of Health, Education, and Welfare Office of Education

ERIC Form 1

R-6 - 18 - Science

8136

Science as Thought

A Study of Nine Academic Year Institutes for the Training of Science Teachers 1958-59

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education

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by

Howard E. Gruber

University of Colorado Behavior Research Laboratory Report No. 16

ED000692

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Academic Year Institutes
for the
Training of Science Teachers
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Preface

In conducting this study the author had one central pre-occupation, the hope that science may someday be taught in such a way that a very broad section of the educated public will understand the scientific process in its most exciting and most characteristic aspect, as a way of intellectual life. The crystallized products of science are easy enough for the layman to see: the technological embodiments of scientific work surround him on every side. Beyond this, the educated public certainly has some sense of the sweep of established scientific ideas and the power of abstract theories to influence practical inventions. This is a very great achievement of public education, and in criticizing education as it stands it would be foolish to ignore this remarkable advance. Nevertheless, the goal of teaching scientific ways of thinking through the teaching of science still seems most intangible, difficult to define, and difficult to invest with practical pedagogical form. And yet it is this aspect of science, science as a way of thought and inquiry, that is most likely to be of value in the long run, especially to the educated but non-scientist public.

In his pre-occupation with this issue, the author has neglected many other things, and the present report suffers accordingly, both in scope and in detail. The author is aware of some of these limitations and accepts full responsibility for them as well as for the opinions expressed in the pages that follow. There is a long list of people to thank for their help and to absolve of any other responsibility: Professor William Briggs, Director of the Academic Year Institute at the University of Colorado during its first two years; Edwin Fields, Associate Director and the teacher of the experimental seminar described below and all the other members of the Executive Committee of AYI at the University of Colorado; the Directors of the nine Academic Year Institutes who cooperated in the collection of data for the national survey: Professor William E. Briggs, University of Colorado; Professor J. W. Cole, Jr., University of Virginia; Professor Freeman D. Miller, University of Michigan; Professor Thomas J. Parmley, University of Utah; Professor R. A. Rogers, Iowa State Teachers College; Professor C. H. Sorum, University of Wisconsin; Professor Charles M. Vaughn, State University of South Dakota; Professor Stanley E. Williamson, Oregon State College; Professor James H. Zant, Oklahoma State University.

Finally, the research assistants who participated in this project at one stage or another: Kirk Brady, Aldora Graf, David Guyol, William King, and John Means. This research was conducted at the Behavior Research Laboratory, which is a subdivision of the Institute of Behavioral Sciences, University of Colorado.

The author is reluctant to set the reader loose without mentioning that the critical tone of this study is only possible because of the willingness and honesty of those being criticized to expose themselves to scrutiny.

Summary

This is a study of nine Academic Year Institutes in which experienced teachers of high school science and mathematics are given advanced training. The major focus of attention was an attempt to evaluate the AYI Fellows' approach to science teaching at the end of the training year; do they approach science teaching in a manner designed to convey the conception of science as a way of thought, or as a set of established facts and doctrines? A total of 202 sample teaching outlines were rated, using blind analysis. At the end of the training year, only 25 per cent of the Fellows were rated "strong" in their concern for teaching about science as a way of thought, and over 60 per cent showed negligible interest in this aspect of science.

A questionnaire permitted some analysis of the Fellows' educational and professional backgrounds, and of the nine AYIs' objectives and methods. Using the per cent of Fellows in each Institute receiving a rating of "strong" on the sample teaching outline as the criterion variable, the most important program characteristic was the proportion of time the particular AYI allotted to methods of teaching requiring the active participation of the individual Fellow in the learning process. Programs ranking high in the use of seminar and laboratory work, and high in the freedom with which Fellows were allowed to choose their own courses, ranked high on the criterion variable. Programs stressing lectures, tests, and prescribed courses ranked low on the criterion variable. Surprisingly, conducting independent research, such as a master's thesis, did not contribute to high performance on the criterion variable, possibly because of the concentration of research topics in science education rather than science proper, and possible because of the small amount of time the Fellow could devote to his research while undertaking a heavy burden of formal courses. The number of hours devoted to academic work per week was negatively correlated with the criterion variable, again suggesting that a certain amount of leisure for thoughtful discussion of the meaning of science was more important than a large amount of academic busy-work.

In every Institute, the response of the Fellows indicated agreement with the major emphasis of the program on science proper rather than on methods of teaching, but the Fellows were equally in agreement in wanting some increases in the proportion of effort devoted to improving methods of teaching. The Fellows were in agreement that the major emphasis was and should be on passive-receptive learning, but wanted somewhat greater opportunity than had been allowed for methods of study involving active participation and independent work. Fellows with strong backgrounds of course-work in science and mathematics before entering AYI were somewhat stronger on the criterion variable, but much course-work was neither a necessary nor a sufficient condition for strong performance on the criterion variable: an unfavorable AYI program could overshadow a favorable educational background.

Fellows with less than 7 years of teaching experience teaching did better on the criterion variable than Fellows with more experience. To the degree that this variable could be separated from chronological age, experience rather than age seemed to be the relevant factor.

From the main study of nine AYIs, as well as in a supplementary study of an experimental seminar, the conclusions seem warranted that high school teachers generally approach science teaching as a matter of conveying science as established facts and doctrines, that training programs stressing passive-receptive teaching methods do little to alter this approach, but that training programs stressing active participation by the Fellows may lead to an approach to science teaching in which science is treated as a way of thought.

Part One

Introduction

One of the most important efforts to improve science education in the United States is the National Science Foundation's program of Academic Year Institutes. High school science and mathematics teachers receive fellowships for a year of advanced study. The training programs, conducted in universities all over the country, focus p imarily on the subject matter of science and mathematics, not on teaching methods.

The present report stems from an evaluation of the first year of the Academic Yea: Institute at the Universi y of Colorado (Gruber, Brady, and Means, 1959). It is an outgrowth of the major criticism of AYI which emerged in the earlier study: the "failure to transmit attitudes and information relevant to teaching science, not only as a body of knowledge, but as a way of thinking" (Gruber, 1960).

The main effort of the evaluation group in the second year was a study of the possibility of producing a different educational outcome of AYI, not subject to the criticism levied above. This work took two forms: first, an experimental effort to influence the way in which one seminar was taught and, secondly, a survey of AYIs all over the country. Although the initial reason for the survey was limited to gaining further information relevant to the criticism described above, the survey produced certain by-products that are of interest in their own right.

It might be well to enter one caveat here. It has always been difficult for us to discuss the problem of transmitting the "scientific attitude" in a rational way. If you say the words "scientific method" when you are somewhere in the vicinity of a strong philosophy department, your companions think of such names as Bridgman, Braithwaite, Carnap, Poincaré, and Reichenbach. But mention "scientific method" near a high school science teacher, and your companions think of some perfectly horrid list of stultifying rules contained in certain books on how to teach science to children. I have even met people who can reel off a list of such rules, memorized 20 years ago. This double meaning of the phrase "scientific method" is strictly a terminological problem, but it can generate much heat. Nevertheless, there seems to be widespread agreement that one can distinguish between teaching science as an established body of knowledge and teaching science as a way of thought.

Chapter One

An Experimental Seminar

The experimental seminar was a regular part of the Academic Year Institute at the University of Colorado. It was generally regarded as an opportunity to cover a miscellany of topics not covered in regular courses and to give the AYI Fellows a chance to discuss possible applications to the high school science teaching situation of what they were learning in their other courses. The main techniques used in the seminar in the previous year 1957-58 had been guest lectures on special topics, demonstrations of teaching methods, and discussion. All of this was repeated in 1958-59, but with one modification: the instructor in charge of the seminar undertook to concentrate his own comments as much as would be appropriate on the general question of the science teacher's task of transmitting something of the scientific attitude as well as specific subject matter knowledge. This was especially important in critical discussions of the Fellows' demonstrations of teaching techniques. In addition, some of the guest lectures were in the area of the philosophy of science.

Finally, a group of specific problems were presented to the Fellows, each one concentrating on some aspect of the process of scientific thought and inquiry. In each of these problems, a brief paragraph pointed out the importance of some facet of scientific work and then presented the Fellows with a problem focussed on that facet. The problems dealt with included the following: formulating answerable questions; designing experiments; drawing inferences and seeing implications; using the literature and history of a subject. Time did not permit us to give the Fellows a large amount of practice with each kind of problem. Nor in the time available was it possible to cover all of the types of problem that seemed important to us -- probably the major omission was the kind of problem concerned with theoretical work. Each problem was formulated in such a way as to draw the Fellows' attention to an aspect of scientific work by describing it briefly and allowing them the opportunity to cope with it for awhile. Although the problems had to be written so that they would be interesting to the AYI Fellows, it was hoped that the problems would actually be examples of the kind of thing that might be done with high school science students, and accordingly, they were labelled "Training Tasks for Teaching Scientific Method."

To evaluate the effectiveness of slanting the seminar in the manner described above, a sample of the Fellows were asked to give a sample teaching performance at the end of the AYI training year. These Fellows were matched with Fellows in the previous year who had given sample teaching performances under the same circumstances, with the exception that the work of the seminar had not been focussed on the problem of transmitting the "scientific attitude." In other respects, the AYI remained approximately the same in the two years under consideration: the other courses taken by the Fellows were not altered in any systematic way, and the procedure for selecting the Fellows from applicants remained the same. From the point of view of experimental control, comparing different groups of individuals at different moments in history leaves something to be desired, but under the circumstances it was the only method available. Even if the method would not permit us to isolate the factors leading to any changes in the sample teaching performances, it would at least be possible to note such changes.

Twenty sample teaching performances had been obtained in 1957-58 and ten in 1958-59, both sets under comparable conditions. This permitted the construction of nine pairs, reasonably well matched for age, intelligence (AGCT, civilian form), and college credits in science and mathematics. From Table 1, it can be seen that the 1957-58 group had slightly higher scores on the intelligence test, and the 1958-59 group had had somewhat more college work in science and mathematics. Using a median test, neither of these difference reaches significance at the .05 level.

Table 1

Description of Fellows in Sample Teaching Performance Study

	1957-58			1958-59		
	N	Median	Range	N	Median	Range
Age	9	31	25-36	9	30	22-42
AGCT	9	143	133-153	9	137	128-150
Science & math. hours	9	55	25-65	9	65	25-115

The sample teaching performances were given by the Fellows chosen for the sample according to the following procedure: the Fellow, who arrived at the laboratory without knowing the task that awaited him, was told that he had half an hour to prepare a talk suitable for a group of high school seniors who had had considerable background in science and mathematics, and that after half an hour's preparation he would actually deliver the talk. The audience for the talk consisted of three people, usually three graduate students in psychology, sometimes two graduate students and one faculty member. To compensate for these somewhat artificial circumstances, efforts were made to keep the atmosphere as informal as possible. Moreover, the Fellows, all experienced teachers, were asked to choose a topic they knew and liked, so that there would be no pressing need to look up reference material. No books were made available. The Fellows reported that although they felt a little ill at ease at first, this feeling soon passed. The "audience" had the same impression. In an interview following each talk, each Fellow was asked if he felt the talk was really the kind of talk he would have given to a group of high school students. Every Fellow replied affirmatively.

Every talk was tape-recorded. Working directly from the tape, a graduate student who had not heard the original talks and did not know the identity of the speaker, or which year's sample the speaker was from, rated each talk on two variables, "science as a way of thought" and "historical orientation." On each variable, a 4-point rating scale was used. On the first scale, a zero rating represents a talk in which science is presented entirely as a body of established facts, while a rating of 3 represents a talk in which science is presented as a way of thought. The person who did the rating summed up the meaning of a rating of 3 as follows: "Science presented as a way of studying, of investigating and of viewing things. Attention to theory, uncertainty, development, leading to information and comparison of ideas or approaches. Informational aspects are incorporated into the process-of-science framework." The intermediate ratings, of course, stand for intermediate cases.

On the second scale, "historical orientation," a rating of zero refers to a talk in which information is presented without any regard for its background. A rating of 3 refers to a talk in which the major emphasis in the talk is the way in which the material presented unfolded historically. In the rater's words, "Orientation is to trace the development of the ideas and information presented. This may be the interrelation of the efforts of a number of investigators or the procedure and course of a single individual's investigations."

It will be noted that the two rating scales deal with partially overlapping issues. It is possible to separate them, but they are not entirely independent. Even if the rater succeeded in the attempt to make independent judgments on each variable, the variables have enough in common to make a composite score as useful as the separate scores. Taking the sum of the ratings for each individual as a composite score, the 1958-59 member of each matched pair was superior to the 1957-58 member in 6 cases, and the scores were identical in the remaining 3 cases. Using Wilcoxon's method for paired replicates, this superiority of the 1958-59 group is significant at the 5 per cent level.

Table 2 presents the actual distribution of the ratings on both variables. It can be seen that most of the ratings on each variable were either 0 or 1. That is, the Fellows gave little or no hint of interest in these matters. For the purpose of evaluating the difference between the two years of AYI, the method of blind anaylsis was a sufficient precaution. But we also wished to avoid underrating the Fellows' performances. The rater was therefore instructed to consider each variable from

two somewhat different points of view: the proportion of the total teaching performance devoted to the issue, and the point in the talk where that issue received its maximum emphasis. As it turned out, the two approaches gave corresponding results. There is little likelihood that the ratings underestimate the Fellows' performances. On the contrary, a rating of 1 probably gives the benefit of the doubt to the Fellow. In our opinion, the bare hints reflected in a rating of 1 are very far from effective level of emphasis sufficient to convey the scientific attitude to students not already imbued with it.

Table 2

Frequency of Different Scores on Sample Teaching Performances

Score	Science as a way of thinking		Historical orientation	
	1957-58	1958-59	1957-58	1958-59
3	1	4	1	4
2	0	0	0	0
1	7	4	1	3
0	1	1	7	2
Total	9	9	9	9

Another way of describing the difference between the sample teaching performances in the two years: in the 1957-58 group only one individual received the maximum rating of 3, this person having been rated 3 on both variables; all other ratings for that year's group were either 1 or 0. In the 1958-59 group, 5 individuals received a rating of 3 on one or both variables. Since it may well be that only those teachers who give strong emphasis to transmitting the scientific attitude are at all effective in doing so, the increase in the number of individuals receiving the maximum rating is all the more important.

When we arranged the matched pairs for the comparison of the two years, we were of course, limited by the group of Fellows available in the second year and by the group of Fellows from whom we had obtained sample teaching performances in the first year. The matching we achieved was one in which the slight superiority of one group in AGCT scores was balanced by the slight superiority of the other group in previous course work in science and mathematics. This was the best we could do, and at the time seemed a reasonable compromise. But in the national survey, to be reported below, we found that Fellows with more background in science and mathematics did better on a sample teaching outline, according to criteria similar to those used in rating the sample teaching performance. It was therefore possible that the superiority of the 1958-59 group in the sample teaching performance might be due simply to their greater background of course-work rather than the experimental seminar described above. Further scrutiny of the data, however, showed that this was not the case. Within the group of 18 Fellows involved in the experiment there was no apparent relation between previous course work and ratings achieved on the sample teaching performance. Indeed, the one Fellow in the 1957-58 group who was rated "strong" on the criterion variable had the weakest background in science and mathematics. Within the 1958-59 group, moreover, where all the remaining "strong" ratings occured, there was no relation between background and performance.

The analysis of the sample teaching performance makes it clear that the Fellows at the University of Colorado AYI, at the end of the first training year, gave little or no evidence that they viewed the task of the high school science teacher as the transmission of the scientific attitude.

On the evidence, one could only conclude that the AYI Fellows would return to the teaching situation somewhat better informed about the subject matter of science but not essentially changed in their approach to it as an established body of knowledge. In the second year of AYI, relatively minor changes in the training program, these changes restricted to a one-credit seminar, produced noticeable changes in the desired direction.

There is a striking similarity between the "training tasks for teaching scientific method" and the techniques developed by Abercrombie (The Anatomy of Judgment, 1960), to achieve similar ends with medical students. Abercrombie's procedures, however lay much greater stress on the role of free discussion among the students. Judging from Abercrombie's favorable results, and from the results of the national survey of AYIs to be described below, such discussions do play an important part in the development of critical scientific thought among individuals whose initial approach to science lays too much weight on a conception of science as the fixed pronouncements of established authorities.

It need hardly be mentioned that the methods so far developed for teaching about science as a way of thought may not be the best possible. In particular, the training tasks may have had a somewhat mechanical quality, although efforts were made to avoid this. It is a difficult pedagogical problem to give the science teacher a good sample of the process of scientific work without involving him in a long apprenticeship as a working scientist; yet without such a sampling it is not easy to see how he can learn to convey the sense of science as an intellectual process. Resolving this dilemma may well require the invention of an entirely new set of teaching methods.

Part Two

National Survey

Hitherto, our examination of the Academic Year Institute has been limited to one institution. What of other AYIs? Are they open to the same criticism? Do the Fellows finishing a year of advanced training in AYIs all over the country return to the high schools prepared to teach science in such a way as to convey the scientific attitude, or do they revert to the teaching of science as an established body of knowledge? Without any information at all about other AYI programs, it would be risky to generalize beyond the one situation which we had studied in some detail. Without a wider perspective, moreover, it is difficult to interpret the difficulties encountered in the AYI at a single institution.

In the academic year 1958-59, there were AYIs in 15 universities all over the country. Ideally, we would have liked to obtain sample teaching performances from AYI Fellows in every program. As this was not feasible, we decided to obtain "sample teaching outlines" in our national survey. The material for the sample teaching outline and a supplementary questionnaire was mailed in April, 1959, to AYI Directors who had indicated that they could participate. In some cases the sample teaching performance and questionnaire were administered in a group session, in other cases they were distributed to individuals. A total of 314 AYI Fellows, from 9 different institutes, responded. This number represents about 70 per cent of the Fellows in the 9 AYIs responding, these 9 AYIs are widely distributed geographically and quite varied academically. The most common reason for failure of an AYI to participate was the fact that they had made other plans for testing, or that their academic programs conflicted with our request for time. All in all, however, it would seem that the 314 Fellows and 9 responding institutions are quite representative of the 15 programs in operation in 1958-59.

The results of this nationwide survey will be presented in three parts: first, the analysis of the sample teaching outline which provided a measure of our criterion variable - the extent to which science teaching emphasizes science as a way of thought; secondly, the description of the various AYI programs; and thirdly, an examination of the relationship between the AYI programs and the criterion variable.

Chapter Two

The Criterion Variable: Teaching Science as a Way of Thought

Although other criteria are obviously relevant, the sole criterion used in this study for evaluating the program of Academic Year Institutes is the extent to which AYI Fellows, at the end of the training year, showed promise of emphasizing the teaching of science as a way of thought. To the extent that these Fellows return to the high school science teaching situation and teach science as a set of established facts and doctrines, the AYI program may be deemed a failure in this important regard.

The Fellows' approach to science teaching was evaluated by analyzing the way in which they handled the task of developing a sample teaching outline.

The task for the sample teaching outline was similar to the task for the sample teaching performance described above, except that no actual talk was to follow the writing of the outline. To make rating possible for us, the Fellows were requested to write their outlines so that another teacher could understand it, i.e., to avoid the cryptic style of some outlines. The instructions for this task are reproduced verbatim in Appendix A.

The sample teaching outlines were rated on two major dimensions: science as a way of thinking and historical orientation. These dimensions have been described above (p. 8). All ratings were done blind, i.e., in ignorance of the institution which the Fellow had attended. The general approach to rating was to give as high a score as possible in order to be sensitive to any hint of concern on the Fellow's part for the dimensions on which we were rating the outline. It is probably safe to say that the rating err, if at all, on the generous side.

To ascertain the reliability with which these outlines could be treated according to our rating system, 43 outlines, approximately an equal number from each school, were rated blind by an additional judge. The extent to which the two judges agreed is shown in Table 3. It can be seen that, on the whole, agreement between the two judges was very good.

Table 3

Percentage Agreement Between Judges for Sample Teaching Outlines

N = 43

Dimension	% agreement	% 1 step disagreement	% 2 step disagreement	% 3 step disagreement
Science	53.5	32.6	9.3	4.7
History	58.1	25.6	7.0	9.3

It was decided not to rate those outlines whose topics were entirely within the field of mathematics. The rater was not qualified to deal with these and, moreover, the rating system did not seem readily applicable to them. A total of 202 outlines were rated.

Table 4 and 5 show the percentage of the sample teaching outlines receiving each rating on the two variables. It can be seen that the national picture is fairly similar to that previously observed in only one AYI. The majority of the Fellows are almost entirely pre-occupied with presenting science as an established body of knowledge. It can be seen that the outlines are fairly homogeneous from institution to institution, with only one major exception, "Institute C." The impression gained from these outlines is perhaps a little more positive than from the sample teaching performances obtained previously. This difference may be due to inter-program differences or, possibly, to the difference between the task of making an outline and the task of presenting a talk, or - lastly - to the deliberately generous policy used in rating the outlines. In any event, there is no reason to abandon the position taken earlier, that in general,science teachers, even at the end of an AYI program, are not much concerned with presenting science as a way of thought.

Table 4

Percent Receiving Each Score on the Dimension:
Science as a way of thinking

		Rating			
Institute	N	0	1	2	3
A	22	54.5	13.6	9.1	22.7
B	33	57.6	27.3	6.1	9.1
C	7	28.6	----	14.3	57.1
D	15	66.7	13.3	6.7	13.3
E	35	31.4	31.4	11.4	25.7
F	35	62.8	8.6	14.3	14.3
G	19	31.6	26.3	21.1	21.1
H	10	60.0	30.0	----	10.0
I	26	42.3	11.5	26.9	19.2
Total	202	49.0%	19.3%	12.8%	18.8%

Table 5

Percent Receiving Each Score on the Dimension:
Historical orientation

		Rating			
Institute	N	0	1	2	3
A	22	59.1	40.9	----	----
B	33	72.7	18.2	----	9.1
C	7	42.9	14.3	14.3	28.6
D	15	73.3	13.3	6.7	6.7
E	35	57.1	28.6	5.7	8.6
F	35	62.8	20.0	5.7	11.4
G	19	63.2	21.1	5.3	10.5
H	10	50.0	40.0	10.0	----
I	26	42.3	30.8	7.7	19.2
Total	202	59.9%	25.2%	5.0%	10.0%

Table 6 shows the relation between the ratings on the two variables. It can be seen that the most frequently occupied cell is in the upper left hand corner, representing a rating of zero on both variables. In order to reduce the data in this 16-cell matrix to a somewhat more comprehensible form, we may subdivide the sample teaching outlines into three major categories as follows: outlines placing a negligible emphasis on both variables (the 00, 01, 10, 11 cells); outlines placing a moderate emphasis on one variable and a negligible emphasis on the other (the 02, 12, 20, 21 cells); and outlines placing a strong emphasis on one or both variables or a moderate emphasis on both variables (the 30, 31, 32, 33, 03, 13, 23, 22 cells). Although these subdivisions are to some extent arbitrary, it is probably reasonable to designate them as negligible, moderate, and strong in their emphasis on conveying the "scientific attitude" in the teaching of science.

Table 6

Frequency Distribution of Different Combinations of

Scores of Sample Teaching Outlines:

Science as a way of thinking

		Rating				
		0	1	2	3	Total
Historical	0	83	21	5	13	122
orientation	1	12	14	13	11	50
Rating	2	1	1	4	4	10
	3	3	3	4	10	20
Total		99	39	26	38	202

Table 7 uses these subdivisions in comparing outlines from the point of view of the topics selected by the Fellows. The similarity among the fields is striking. The "miscellaneous" category includes talks that might be classified as general science, geology, psychology, forestry, etc. This category suffers slightly by comparison with the others.

Table 7 also provides a convenient way of characterizing the entire set of teaching performances: toward the end of a year of advanced training specially designed for high school teachers, nearly two-thirds of the Fellows showed only a negligible concern for conveying the scientific attitude.

Table 7

Emphasis on Conveying Scientific Attitude:

Sample Teaching Outlines Subdivided by Topic

	Degree of Emphasis							
	Negligible		Moderate		Strong		Total	
	N	%	N	%	N	%	N	%*
Biology	46	62.2	7	9.4	21	28.4	74	100
Physics	45	61.6	7	9.6	21	28.8	73	100
Chemistry	25	69.5	2	5.5	9	25.0	36	100
Miscellaneous	14	73.7	4	21.0	1	5.3	19	100
Total	130	64.4	20	9.9	52	25.7	202	100

*Percentages are totalled horizontally

The 9 AYIs were ranked with respect to the per cent of Fellows receiving a 2 or 3 rating on the sample teaching outline on each of the two variables. The rank order correlation obtained from these rankings was rho = .73.[1] It should be pointed out that this is a correlation between institutional performances; the relation between the same two variables when we consider individual performances is much lower. The fact that the correlation is as high as it is suggests that insofar as institutional or program characteristics are concerned, the two variables - science as a way of though and historical orientation - are measuring the same thing: the extent to which Fellows spending a year in a given program come to emphasize the transmission of the scientific attitude in their own teaching.

[1]With nine pair of observations the correlation must equal or exceed rho = .666 for significance at the 5 per cent level of confidence.

Table 8

Description of Fellows in Nine Academic Year Institutes

Institute	Years Teaching		Age		Semester hours Science & Math.		N		
	Median	Range	Median	Range	Median	Range	Male	Female	Total
A	6.5	2-21	34	23-46	55	10-130	35	5	40
B	7	2-24	32	25-55	65	20-145	47	2	49
C	7	4-16	32	26-46	75	20-90	7	2	9
D	5	1-33	32	24-54	60	20-135	27	3	30
E	5	3-20	32	25-53	70	20-165	38	3	41
F	6	2-22	34	25-49	60	20-120	45	3	48
G	6	3-18	33	26-47	55	10-120	31	0	31
H	6	2-29	33	26-53	45	10-130	13	10	23
I	5	2-14	31	25-40	60	10-100	40	3	43
Total	5.8	1-33	32.5	23-55	56.8	10-165	283	31	314

Chapter Three

Nine AYI Programs

The 9 AYI programs will be described under three main headings: first, background characteristics of the AYI Fellows; secondly, objectives of the AYI as seen by the Fellows; and thirdly, teaching methods used in the AYI as reported by the Fellows.

Fellows' Characteristics: age, experience, and educational background.

Table 8 summarizes the findings on a number of variables. It can be seen that the groups of Fellows responding from the 9 AYI programs are quite similar in most respects. Although the range within each institution is extremely wide, all institutions seem to have followed a similar policy of selecting Fellows diverse in educational background, age and teaching experience. The results of this flexible policy, however, produced a fairly homogeneous group of Fellows. The median age was 32.5 years, with 216 Fellows, or 68.5 per cent, in the 25-35 year group. The median number of years teaching was 5.8, with 209 Fellows, or 66.6 per cent, in the 2-7 year group. The median number of semester hours of science and mathematics before entering AYI was 56 8, with 212 Fellows, or 68.5 per cent in the 30-80 hours group. If number of semester hours were the only criterion of adequate preparation for teaching, by no means all of the Fellows were inadequately prepared for science teaching on entering the program: 68 Fellows, or 22 per cent, had 80 semester hours or more of previous work in science and mathematics. Our questionnaire was not sufficiently detailed to reveal the specific features of each Fellow's background which might have explained the admission to AYI of so many Fellows who had already had so much course-work in science and mathematics.

Fellows' Characteristics: areas of specialization.

Table 9 gives the distribution of the various areas of specialization at three points in the Fellow's career: his undergraduate major, his major teaching area, and his AYI specialty. With respect to the number of Fellows involved, the order at every level is: mathematics, biology, chemistry, physics. Physics shows a steady rise from 5 individuals, or less than 2 per cent of undergraduate majors, to an unspectacular 44 individuals, or 13.8 per cent specializing in physics at AYI.

Table 9

Frequencies of Different Areas of Specialization of AYI Fellows

	Undergraduate Major	Major Teaching Area	AYI Specialty
Mathematics	84	118	95
Biology	54	69	68
Chemistry	34	47	52
Physics	5	18	44
Other	137	62	55
Total	314	314	314

Note: the "other" category for undergraduate majors includes general science (28), education (18), miscellaneous (91). For teaching areas it includes general science (36), elementary education (4), miscellaneous non-science teaching and administrative work (22). For AYI specialty, the "other" category remains entirely within the domain of science and mathematics, involving various combinations of subjects.

On the whole, there is a fairly strong relation between the Fellows' majors in college and their

teaching areas in high school, this in contradiction to remarks sometimes heard on the subject. Nevertheless, this relationship is not constant, but a variable, both with respect to individuals and institutions, and it might be worth studying in more detail.

Objectives of the Academic Year Institute.

The clearcut formulation of objectives is one of the most difficult aspects of educational experimentation. Most innovations, such as AYI, are inaugurated in an atmosphere of haste and practicality tinged with a due regard for the opinions of the planning group's professorial confrères, many of whom can be expected to be out of sympathy with the experiment. This situation does not invite the kind of program-building which starts from the ground up with a fresh formulation of objectives and the selection or invention of the most appropriate techniques. Rather, the innovating group sketches a few very broad, ill-defined objectives and then sets about in an attempt to realize them with the least possible disturbance of the educational status quo. This is a comparatively fast and inoffensive way of "getting things done," but it often ineffective and might well turn out to be beside the point if one only knew what the point was. The difficulty is compounded when the "experiment" is an entire educational program that does not have a single objective and cannot use a single technique. The shaping of a program, one would think, would require the most careful formulation of the entire set of objectives. A rational approach might involve listing and classifying goals, assigning priorities or weights, considering alternative sequences of activities, and estimating the probable contribution of each major technique to each objective. In the writer's experience, having observed a number of experimental programs in the making, this description is so far from practice as to be fantastic. No part of the educational process is slighted more or, if handled at all, handled more irrationally than the formulation of objectives.

The material that follows is an attempt to describe the objectives of the AYI as seen through the eyes of 313 AYI Fellows in 9 AYI programs. Although our data are limited in a number of ways, especially in the lack of information about AYI objectives as seen by the Faculty, it may still provide a useful spring-board for discussion of AYI objectives.

The questionnaire devised for the purpose was intended to give a picture of the program's objectives as a whole. One reasonable procedure would have been to ask the Fellows to rank-order a set of objectives as to their importance. But rank orders do not give any indication of the distances between adjacent ranks, or of the absolute weight of each item in the set of items. In short, we wanted a method that would consider a set of possible objectives as a whole and would give some sort of quantitative picture of the relations among these objectives. The method used is to ask the respondent to subdivide the effort expended in his program into two major parts, percent of effort devoted to increasing knowledge and skills and percent of effort devoted to improving teaching techniques. In a second step each of these two parts is then further subdivided into a number of sub-goals. The process is carried out twice, once for a description of the AYI program as it is now conducted and again for the Fellow's conception of the ideal program. Although the task seems complicated at first sight, it turns out to be simple enough. The section of the questionnaire dealing with program objectives is reproduced in full as Appendix B.

Tables 10, 11, 12 give the results of the questionnaire dealing with program objectives. A number of interesting points emerge. With very few exceptions, there are striking similarities among the programs. Approximately 85 per cent of total effort is devoted to increasing knowledge and skills in science and mathematics with the remainder devoted to improving teaching techniques. As can be seen from Table 10, which describes the Fellows' impressions of the actual programs, the major exception is Institute H, which devoted about 30 per cent of its effort to improving teaching techniques, as compared with a mean of 14.3 per cent for all schools combin[illegible].

In every program, the most important single objective is "increasing knowledge and skills in standard subject matter." In 7 out of 9 AYIs the effort devoted to this objective is seen by the Fellows as greater than 50 per cent. Institute H, which devoted only 39.6 per cent of its effort to this objective, devoted correspondingly more to "improving teaching techniques." The only other AYI in which effort devoted to standard subject matter was less than 50 per cent (Institute I, mean = 44.4 per cent) devoted correspondingly more effort to "increasing knowledge and skills in

Table 10

ACTUAL PROGRAM: PERCENTAGE OF EFFORT SPENT ON PROGRAM OBJECTIVES

		Program Objectives									
		Increasing knowledge and skills in					Improving teaching techniques for				
N	Institute	Standard Subject Matter	New developments	History & Philos.	Scientific Method	Total	Standard Subject Matter	New developments	History & Philos.	Scientific Method	Total
40	A	58.0	21.2	5.6	5.8	90.6	3.5	4.0	0.7	1.2	9.4
49	B	51.5	19.1	4.4	5.9	80.9	7.7	6.3	2.1	3.0	19.1
9	C	59.5	18.4	4.6	4.2	86.7	7.7	5.4	0.1	0.1	13.3
30	D	56.8	19.7	5.6	6.8	88.9	4.4	3.5	1.1	2.1	11.1
41	E	54.7	16.6	7.2	5.6	84.1	4.6	4.7	2.5	4.1	15.9
48	F	62.7	13.0	7.1	7.1	89.9	3.4	2.9	1.9	1.9	10.1
30	G	55.4	20.7	7.4	5.1	88.6	3.8	4.6	2.0	1.0	11.4
23	H	39.6	20.2	4.0	5.6	69.4	12.7	10.7	3.3	3.9	30.6
43	I	44.4	27.6	7.8	5.8	85.6	3.9	6.6	1.7	2.2	14.4
313	Mean	53.8	19.5	6.1	6.0	85.4	5.3	5.1	1.5	2.4	14.3

Table 11

IDEAL PROGRAM: PERCENTAGE OF EFFORT SPENT ON PROGRAM OBJECTIVES

		Program Objectives									
		Increasing knowledge and skills in					Improving teaching techniques for				
N	Institute	Standard Subject Matter	New developments	History & Philos.	Scientific Method	Total	Standard Subject Matter	New developments	History & Philos.	Scientific Method	Total
40	A	41.2	24.9	7.2	7.2	80.5	5.6	7.7	2.6	3.6	19.5
49	B	43.2	22.5	4.2	5.9	75.8	8.9	8.3	2.2	4.8	24.2
9	C	48.1	15.0	7.2	7.5	77.8	7.9	8.3	2.6	3.4	22.2
30	D	41.3	21.8	7.0	7.0	77.1	6.2	9.4	3.4	3.9	22.9
41	E	38.2	20.3	8.3	8.5	75.3	6.4	7.2	4.9	6.2	24.7
48	F	45.1	14.7	6.5	8.0	74.3	10.4	6.8	3.5	5.0	25.7
30	G	45.8	21.2	6.7	4.7	78.4	6.6	9.1	2.7	3.2	21.6
23	H	32.0	24.8	5.4	5.5	67.7	10.7	12.6	4.6	4.4	32.3
43	I	29.9	25.9	7.0	8.1	70.9	8.3	12.8	3.9	4.1	29.1
3 13	Mean	40.1	21.6	6.6	7.0	75.3	7.9	9.0	3.4	4.4	24.7

Table 12

DIRECTION OF DESIRED CHANGE
IN
PERCENTAGE OF EFFORT SPENT ON PROGRAM OBJECTIVES
(Ideal minus Actual)

	Program Objectives								
	Increasing knowledge and skills in				Improving teaching techniques for				
Institutes	Standard Subject Matter	New developments	History & Philos.	Scientific Method	Standard Subject Matter	New developments	History & Philos.	Scientific Method
A	-	+	+	+	+	+	+	+
B	-	+	-	0	+	+	+	+
C	-	-	+	+	+	+	+	+
D	-	+	+	+	+	+	+	+
E	-	+	+	+	+	+	+	+
F	-	+	-	+	+	+	+	+
G	-	+	-	-	+	+	+	+
H	-	+	+	-	-	+	+	+
I	-	-	-	+	+	+	+	+
Total: +	0	7	5	6	8	9	9	9
0	0	0	0	1	0	0	0	0
-	9	2	4	2	1	0	0	0

+ indicates desire for more emphasis on a given objective.
- indicates desire for less emphasis on a given objective.

new developments" and to the history and philosophy of science, this AYI having been the most energetic of the nine in both of these respects.

Table 11 gives the Fellows' conceptions of the ideal AYI program. Comparing Tables 10 and 11 gives some idea of the kind of changes that the Fellows would like to see. From actual to ideal, there is a 13.7 per cent drop in the mean per cent effort assigned to the first objective, increasing knowledge and skills in standard subject matter. The time and energy to be saved by this proposed change would, according to the Fellows be distributed over all of the other objectives. Nevertheless, the rank order of the objectives remains about the same, the only changes being in some of the middle-ranked objectives. In effect, the Fellows are recommending a conservative change. They would like to retain approximately the same ordering of objectives as is now the case, but since so much effort was devoted to the first objective, emphasis on it can be reduced without its yielding first place. Although the discrepancies between actual and ideal program objectives are very small in many cases, the consistency of the direction of desired change, as shown in Table 12, can be taken as an indication that the Fellows in every AYI studied experienced similar problems: they appreciate and agree with the emphasis on the primary objective, but they feel somewhat at a loss to know how they are going to use what they learn in AYI when they return to the teaching situation. It may be that relatively slight changes in the programs could rectify this problem. The mean over all schools would like to see the per cent of effort devoted to improving teaching techniques raised from 14.3 per cent to 24.7 per cent. Even the Fellows at Institute H, where much more effort than elsewhere was devoted to improving teaching techniques, would like to have still more work on that group of objectives. But the discrepancy between actual and ideal for that group of objectives is smallest at Institute H, which suggests that AYI Fellows are not insatiable in their desire for more work on how to teach. Moreover, the Fellows at the latter AYI wanted less work on improving teaching methods for standard subject matter, again suggesting that the Fellows' appetites for this kind of training can be satisfied while still maintaining primary emphasis on the announced main objective of AYI.

The results reported in this section have, of course, many limitations. The Fellows' opinions were not necessarily based on systematic, searching examination of the issues or on attempts to assess the attainability of the set of objectives in accordance with their supposed importance. If the Fellows had been given the opportunity for this kind of thought, they might have been even more conservative in the changes they suggested; then again, they might have proposed much more sweeping changes. The major change the Fellows seem to be proposing, somewhat greater emphasis on improving teaching techniques, grows out of their own personal experiences as teachers. The fact that the Fellows are not equally consistent in favoring more emphasis on increasing their own grasp of scientific method and the history and philosophy of science may simply mean that these areas are beyond the ken of most of the Fellows. Certainly, that is the conclusion one would draw from examining the sample teaching outlines and performances. At any rate, taken for what they are worth, the results in this section may be considered as a description and criticism of program objectives from the peculiar vantage point of an AYI Fellow finishing one year in AYI.

Teaching Methods Used in AYI.

In describing the operation of the various AYIs, we were interested in coming as close as possible to the actual behavior of the Fellows. From the concrete descriptive matter reported in the questionnaires, we were able to move to a somewhat more general description in terms of a broader system of classifying kinds of academic behavior.

The questionnaire dealing with teaching methods presented the Fellows with a list of 17 different behaviors: various kinds of class work, laboratory work, reading, discussing, studying, and test taking. The Fellow was requested to indicate the percent of time in an average academic work week that he had devoted to each behavior during the AYI year. He was then asked to repeat this process for his conception of an ideal AYI program.

The 17 behaviors were classified into three major groups: the passive-receptive group includes attending lecture classes, reading assigned textbooks, reading other assigned materials, studying and reviewing class notes, doing problems and similar short assignments, taking objective tests, and taking essay tests; the active participation group includes attending seminar or discussion classes, attending

laboratory demonstrations and doing laboratory exercises, out of class discussions with students, and out of class discussions with teachers; the independent study group includes reading unassigned materials, doing independent laboratory work, working on thesis, writing term papers, working on term project, and independent reflective thought. This classification was made on an a priori basis, without reference to the results of the questionnaire.

Table 13 gives the results of the questionnaire dealing with the distribution of the Fellows' efforts over these 3 main classes of academic behavior. The differences between schools seem relatively slight, but as will be shown in the next section, these differences were probably large enough to account for some of the differences in educational outcomes produced by the 9 AYIs. The comparison of actual and ideal programs shows an almost perfectly uniform desire of the Fellows in every school for a reduction in passive-receptive activities and an increase in active participation and independent study. Again, it should be pointed out that the figures in Table 14 are mean responses for each AYI. The individuals within an AYI were, of course, somewhat more variable.

Table 13

DISTRIBUTION OF TIME IN ACADEMIC WORK WEEK:

ACTUAL AND IDEAL PROGRAMS

Institute	N	Actual Program			Ideal Program		
		Passive-Receptive	Active Participation	Independent Study	Passive-Receptive	Active Participation	Independent Study
		%	%	%	%	%	%
A	40	67.70	16.90	14.60	60.20	18.70	20.10
B	49	62.00	18.90	18.10	59.40	19.80	20.50
C	9	62.80	24.90	12.30	51.20	33.30	15.50
D	30	69.10	15.90	14.70	62.30	18.60	18.50
E	41	64.00	22.60	12.90	54.30	25.00	20.30
F	48	67.40	19.00	13.40	59.70	20.60	19.40
G	31	66.70	13.40	19.60	60.70	20.50	17.80
H	23	70.20	15.50	14.10	54.70	22.70	22.10
I	42	63.00	20.30	16.10	56.00	22.80	20.40
Mean	313	65.72	18.42	15.34	58.36	21.40	19.79

Table 14 summarizes the discrepancies between actual and ideal programs and brings home the uniformity of the Fellows' desire for change. As before, in the results for program objectives, the desire for change in teaching methods is moderate. The Fellows in every AYI would want more than one-half of their efforts in an ideal program to be devoted to passive-receptive behaviors. Nevertheless, the uniformity in the direction of desired change is striking, and indicates that the AYI Fellows as a group feel that they would profit from a reduction in the amount of academic spoonfeeding which has received so much public discussion in recent years.

Table 15 summarizes program characteristics not dealt with in the previous question. Column 1 gives the mean number of hours per week reportedly spent on academic work in an average week. In every AYI the Fellows were a hardworking lot, the minimum reported being a mean of 56 hours per week for Institute E. But the difference between this minimum and the maximum of 71 hours given by Institute F is impressive too. Column 2 gives the per cent of Fellows in each AYI reporting that all or most of their individual programs of study were elective courses.

Column 3 of Table 15 gives the per cent of Fellows in each AYI who were working for an advanced degree, almost all of them in every AYI. Columns 4, 5, and 6 give the percent of Fellows checking each response to the question, "Are you working on a theses or other research paper: thesis,

research, paper, none?" In 5 AYIs almost none of the Fellows reported that they were working on a thesis or other research paper. In only one AYI, Institute G, were most of the Fellows working on a thesis. Even in Institute G, which devoted far more attention than any other institute to the thesis or research paper, the mean per cent of time devoted to this aspect of academic work was only 10.5 per cent of the academic work week. In the institute ranking second in this regard, Institue D, 73.3 per cent of the Fellows reported working on a research paper (rather than a thesis), and the mean per cent of time devoted to this research was 3.4 per cent of the academic work week.

Table 14

DIRECTION OF DESIRED CHANGE
IN
DISTRIBUTION OF TIME IN ACADEMIC WORK WEEK
(Ideal minus Actual)

Institute	Passive-Receptive	Active Participation	Independent Study
A	-	+	+
B	-	+	+
C	-	+	+
D	-	+	+
E	-	+	+
F	-	+	+
G	-	+	-
H	-	+	+
I	-	+	+

\+ indicates desire for more time in category of behavior

\- indicates desire for less time in category of behavior

Table 15

Miscellaneous Program Characteristics

Institute	1 Mean Hours Per Week	2 Per Cent Electives	3 Per Cent Degree Programs	4 Per Cent Thesis	5 Per Cent Research Paper	6 Per Cent No Research
A	58.2	60.0	85.0	12.5	7.5	80.0
B	64.0	65.3	89.8	8.2	12.2	79.6
C	57.1	88.9	100.0	----	----	100.0
D	62.5	66.6	96.7	----	73.3	36.7
E	56.3	90.2	100.0	2.4	7.3	90.2
F	71.2	39.6	97.9	29.2	20.8	50.0
G	59.8	83.8	93.5	74.2	----	25.8
H	65.4	66.6	95.5	----	----	100.0
I	59.7	86.0	97.7	4.8	54.8	40.5

What kind of research can be done by Fellows carrying a heavy course load and devoting such a small part of their time to the research? Our data on this point are scanty. The questionnaire in-

cluded space for a brief description of the research, if any, that the Fellow was doing. An attempt was made to classify the descriptions into two categories: science or mathematics proper, and science education. For Institute G, ranked highest in per cent of Fellows doing research, 2 of the theses were in science proper and 21 dealt with educational topics. For Institue D, ranking second in per cent of Fellows doing research, 6 research papers were in science proper and 7 dealt with educational topics. For Institute I, ranking third in per cent of Fellows doing research, 6 dealt with science proper, 12 with topics in science education.

A sampling of the Fellows' descriptions of their research follows: Institute D, research paper: "I made an extensive study of ovidation-reduction reactions, experimental methods of determining ovidation potential and the relation of thermodynamic entities to the ovidation potential." Classified as science proper.

Institute D, research paper: "A study of cosmic rays." Classified as science proper.

Institute D, research paper: "Dissection techniques for high school biology teachers." Classified as science education.

Institute G, thesis: "Appraising the science program in the county in which I taught and will be teaching. Using questionnaires and research reading to establish criteria." Classified as science education.

Institute G, thesis: "A study of the use of science projects as a means of improving science instruction in the secondary school." Classified as science education

Institute G, thesis: "Preparation of a textbook, workbook, and a teacher resource manual for teaching a unit on heredity to an 8th or 9th grade general science class." Classified as science education.

Institute G, thesis: "I did research on the work that has been done in motivation in secondary math and attempted to formulate a plan of motivation." Classified as science education.

Although the available information was far too sketchy for a satisfactory description, the writer's personal impression includes considerable doubt as to the value of these theses and research papers, either as contributions to science or to the training of the Fellows. It may well be that too little time was allotted to the theses and research papers to produce much of value at the graduate level. The writer's guess is that time spent on a thesis is usually well spent only if the student has very few other academic burdens.

Chapter Four

Variables Affecting Approach to Teaching

It should be a commonplace that the outcome of any educational program will depend on the characteristics of those being educated and on the nature of the program. In this section we are especially interested in the relations among three groups of variables: the background characteristics of the Fellows, the nature of the AYI training programs, and the educational outcome as reflected in attempts to convey the scientific attitude in high school science teaching.

Table 16 assembles the results for each training program for each of 8 variables. The results of the first 6 columns have been presented previously in this report. With regard to years of teaching experience, it was noticed that although the median number of years of experience reported by the Fellows in each AYI did not seem to be related to performance on the criterion, the homogeneity of the group did seem to be related. Therefore, column 7 indicates the per cent of Fellows in each AYI falling in the range, 4-7 years experience. The criterion variable, shown in the last column in Table 16 indicates the per cent of Fellows in each AYI whose performance on the sample teaching outline reflected strong emphasis on attempts to convey the scientific attitude in high school teaching.

Table 17 gives all possible rank-order correlations among these 8 variables. A number of points stand out. Performance on the criterion variable is significantly correlated with the Fellows' backgrounds and with characteristics of the training programs. The more active participation and the more elective choice of individual program of study allowed by an AYI, the better its Fellows did on the criterion variable. Likewise, the more an AYI selected Fellows with better previous preparation in science and mathematics, the better the Fellows from that AYI did on the criterion variable. On the other hand, the harder the Fellows worked, the more poorly they did on the criterion variable.

If we were to consider only the relation between the criterion variable and the training variables, the following simple and plausible picture would emerge: A permissive atmosphere, facilitating much discussion, laboratory work, and elective course work mainly in the form of seminars, fosters the kind of intellectual growth leading to attempts to convey the scientific attitude when teaching; while a highly directive atmosphere, emphasizing many lectures and tests and much busy-work fosters the kind of intellectual growth leading to attempts to teach high school science as facts and doctrine.

On the other hand, if we were to consider only the relation between the criterion variable and the background variables, it would appear that the more an AYI concentrated on selecting Fellows who already had a good background in science and mathematics, the better it could expect those Fellows to perform on the criterion variable. Moreover, better performance on the criterion variable occurred in AYIs with a higher percentage of Fellows with 4-7 years of teaching experience.

The two sets of relationships are not mutually exclusive. Indeed, the AYI whose Fellows did best on the criterion variable ranked highest or second highest on all the relevant training and background variables.

The pattern of correlations might conceivably permit another interpretation: that the character of the training program does not affect performance on our particular criterion variable, so long as the Fellows are selected carefully. This is not borne out. Institute B ranked third on number of hours of science and mathematics and third on percentage of Fellows in the favorable 4-7 years experience range, yet its Fellows ranked eighth on the criterion variable.

Another possible interpretation of the results might suggest that the criterion variable was so difficult to attain that only exceptionally well qualified Fellows could be expected to exhibit it, even after a year in AYI. If this were so, only Fellows with many courses in science and mathematics before entering AYI should have been rated high on the criterion variable. A closer examination of the available data does not bear this out. Of 79 Fellows with fewer than 60 semester hours of science and mathematics, 22, or 27.9 per cent, were ranked either strong or moderate on the criterion variable; of 88 Fellows with 70 hours or more, 36 or 40.8 per cent were rated either strong or moderate. The difference in proportions is not statistically significant (chi-square = 2.69, df = 1, $p > .10$). Of the 9

Table 16

SUMMARY OF MOST RELEVANT VARIABLES

Institute	Passive Receptive	Independent Study	Active Participation	Electives	Hours Worked	Science & Math Hours	Teaching Experience	Criterion
	1	2	3	4	5	6	7	8
A	67.70	14.60	16.90	60.0	58.15	55	40.0	22.7
B	62.00	18.10	18.90	65.3	63.96	65	49.0	12.1
C	62.80	12.30	24.90	88.9	57.11	75	55.5	57.1
D	69.10	14.70	15.90	66.6	62.46	60	23.3	13.3
E	64.00	12.90	22.60	90.2	56.27	70	46.4	37.2
F	67.40	13.40	19.00	39.6	71.22	60	39.6	22.8
G	66.70	19.60	13.40	83.8	59.77	55	48.4	31.7
H	70.20	14.10	15.50	66.6	65.35	45	45.8	10.0
I	63.00	16.10	20.30	86.0	57.74	60	51.1	34.6

KEY TO COLUMN HEADINGS

1. Mean per cent of time devoted to educational activities classified as passive-receptive.
2. Mean per cent of time devoted to educational activities classified as independent study.
3. Mean per cent of time devoted to educational activities classified as active participation.
4. Per cent of Fellows reporting that all or most of their individual programs of study were elective courses.
5. Mean hours per week spent on academic work.
6. Median semester hours of science and mathematics before entering AYI.
7. Percent of Fellows falling in range, 4-7 years experience.
8. Percent of Fellows rated strong on the criterion variable: teaching science as thought.

Table 17

AYI PROGRAM, BACKGROUND, AND CRITERION VARIABLES:

RANK ORDER CORRELATIONS

	1	2	3	4	5	6	7	8
1		-.067	-.633	-.371	.434	-.713 *	-.590	-.518
2			-.633	-.229	.267	-.396	-.113	-.400
3				.429	-.572	.846 **	.500	.700 *
4					-.804 **	.475	.579	.688 *
5						-.596	-.434	-.783 *
6							.588	.604
7								.608

KEY TO COLUMN HEADINGS

1. Mean per cent of time devoted to educational activities classified as passive-receptive.
2. Mean per cent of time devoted to educational activities classified as independent study.
3. Mean per cent of time devoted to educational activities classified as active participation.
4. Per cent of Fellows reporting that all or most of their individual programs of study were elective courses.
5. Mean hours per week spent on academic work.
6. Median semester hours of science and mathematics before entering AYI.
7. Percent of Fellows falling in the range, 4-7 years experience.
8. Percent of Fellows rated strong on the criterion variable: teaching science as thought:

* Significant beyond the 5 per cent level of confidence.
** Significant beyond the 1 per cent level of confidence.

Fellows at Institute I rated "strong" on the criterion variable, 4 had less than 50 hours of science and mathematics before entering AYI. Of the 5 Fellows at Institute A rated "strong" on the criterion variable, 3 had less than 50 hours of science and mathematics before entering AYI. It is interesting that in both of these AYIs some special effort seems to have been made in connection with the criterion variable. The Fellows from Institute I, for example, reported more effort devoted to "increasing knowledge and skills in the history and philosophy of science" than any other AYI.

All in all, then, a strong background in science and mathematics courses was neither necessary nor sufficient for high performance on the criterion variable. The most plausible interpretation of the results under discussion may be that the inclusion in an AYI of many Fellows well trained in science and mathematics was one of several factors contributing to the kind of atmosphere in which the relevant kind of intellectual growth might ensue For example, if there were many Fellows with much previous course work in a given AYI, it would be likely that the faculty would arrange more of the program on an informal seminar basis, rather than restricting it to highly structured courses covering standard subject matter fundamentals. The benefit of the greater opportunities for active participation would accrue to all the Fellows, not only to those with the larger number of previous courses.

When we turn to the years of teaching experience of the Fellows, the picture is somewhat different. The more experienced Fellows did not rate as high on the criterion variable. Of 144 Fellows in the low experience range, 1-8 years of teaching, 46 Fellows, or 31.9 per cent were rated "strong" on the criterion variable. Of 47 Fellows in the high experience range, 9 or more years, 6 Fellows, or 12.8 per cent were rated "strong." This superiority of the less experienced Fellows was statistically significant, as tested by chi-square (omitting the few Fellows rated "moderate" on the criterion variable, chi-square = 5.53, df = 1, $p < .02$).

In evaluating the effects of chronological age and years of teaching experience on the criterion variables, it must be kept in mind that age and professional experience are correlated with each other. The correlation, however, is not perfect, and it is possible to find some "old novices" and some who are young but experienced. This permits us to separate the effects of the two variables. In Table 18 "young" means 36 years or younger and "old" means old than 36; "novice" means 6 years of less of teaching and "experienced" means more than 6 years of teaching; "percent strong" refers to the percentage in each category rated "strong" on the criterion variable.

Table 18

Effects of Chronological Age and Teaching Experience on

Attempts to Transmit Scientific Attitude

	N	Percent strong
Young Novice	100	35.0
Old Novice	16	25.0
Young Experienced	38	21.0
Old Experienced	40	12.5

Naturally, most of the cases fall in either the "young novice" or "old experienced" categories, while our power to distinguish the effects of chronological and vocational age from each other depends on having an ample number of cases in the other two categories. As far as these data go, it can be seen that years of teaching experience is probably a more important consideration than chronological age. "Old novices" are relatively good risks at least as far as the present criterion variable goes. The old adage should probably be revised to read "You can't teach an old hand new tricks."

To sum up: if we take the criterion variable seriously and select our training methods from among those used by the 9 AYIs under consideration, we can expect best results if we select Fellows with less than 9 years of teaching experience, and within very wide limits we can afford to ignore the number of science and mathematics courses in the Fellow's previous background. Other considerations might lead us to select Fellows with weaker backgrounds, since they are probably the ones who, in respects not

touched by the present criterion variable, need additional training most. As for the older or more experienced teachers, it should be pointed out that the present results really should not be generalized to training procedures other than those used by the AYIs under investigation. An inventive attack on the problem of teaching teachers to convey the scientific attitude might well produce methods that would get good results with the more experienced Fellows as well as with the "novices."

Chapter Five

Discussion

In so far as they are comparable, the results of the national survey confirm the previous findings in the study of a single AYI. At the end of a year of advanced training, only a minority of AYI Fellows, (about 30 per cent) demonstrate any appreciable concern for teaching about science as a way of thought rather than as established doctrine.

The national survey reveals considerable unanimity among the Fellows in their reactions to AYI. They are very favorably impressed by AYI and their expressions of desire for change in the training program are quite moderate. The Fellows want to preserve the learning of subject matter knowledge as the primary objective of AYI and keep the learning of new teaching techniques as a secondary objective; but they would like somewhat greater emphasis on this secondary objective. Within the domain of subject matter knowledge they would like somewhat less emphasis on "standard" topics and a little more on such things as new developments and scientific method. Although our earlier study suggests that the Fellows may be profoundly ignorant of the history and philosophy of science, there is no clearcut sentiment among them for more study of these subjects.

With regard to educational methods, the Fellows are similarly cautious but unanimous in recommending change. They report that the preponderance of time in AYI was spent on methods that we have called "passive-receptive" (listening to lectures, doing assigned reading in textbooks and other assigned 'homework', and taking tests), and they would like to keep it that way. But in every AYI studied the Fellows would like the time spent on such activities reduced a little, the time saved to be employed in giving greater weight to educational methods involving more active participation and independent study.

Although the 9 AYIs studied show many similarities, the differences among them are interesting and are large enough to account for some of the differences in the criterion variable, i.e., the Fellows' concern for teaching science as a way of though, as evidenced in their sample teaching outlines.

Institutes C, E, and I were the three ranked highest on the criterion variable. These three AYIs were the ones that devoted the most time to educational methods requiring active participation of the Fellows and that gave their Fellows the freest choice of electives in their courses. Institute H, ranking lowest on the criterion variable, devoted the most time to educational methods in which the Fellows' role can be described as "passive-receptive."

The Fellows at all the AYIs seem to have worked very hard, 56 hours per week of academic work being the lowest mean among the 9 AYIs. But harder and harder work was not the formula for success according to our criterion variable. The three top AYIs on the criterion variable, Institutes C, E, and I had the three lowest mean hours worked per week.

The picture that emerges, then, of an AYI that performed well on the criterion variable (concern for teaching science as a way of thought) is of a program that treated its Fellows in a mature way, allowing time for discussion of ideas and opportunity for individual slection of courses, and avoiding overdoses of scholastic busy-work.

Not surprisingly, Fellows with strong backgrounds in science and mathematics courses before entering AYI performed better on the criterion variable that Fellows with weak backgrounds. But a strong background was neither a necessary nor a sufficient condition for good performance on the criterion variable. Some Fellows with poor background did well and some with many academic credits in science and mathematics behind them did badly. The specific character of the AYI program made a definite difference. For example, Institute B, which ranked third in previous course work (mean = 65 semester hours) ranked eighth on the criterion variable, fifth in opportunity for active participation, seventh in opportunity for elective choice of courses, and third in number of hours worked per week. This pattern suggests that favorable educational backgrounds can be overshadowed by an unfavorable training program.

Our description of AYI program characteristics and our analysis of the Fellows' performances on the sample teaching outline are not based on entirely independent sets of observations, since the same

group of Fellows supplied both kinds of data. We have argued that program differences explain, in part, the variation in Fellows' performances. But another interpretation was possible: the individual Fellow's answers to the questionnaire may have been related to performance on the criterion variable merely because both kinds of response were influenced by some as yet unidentified underlying variable. For Example, more advanced Fellows might have actually received different treatment, or they might have simply perceived AYI differently. To test this possibility, the Fellows were subdivided according to their performance on the criterion variable and their questionnaire responses examined for any systematic differences in descriptions of the AYI programs they had attended. The differences found were nil: Fellows rated "strong" on the criterion variable and Fellows rated "negligible" gave virtually identical descriptions of their AYI programs. On this ground at least, then, there is no reason to doubt the causal connection between program characteristics and Fellows' performances.

As discussed earlier, both chronological age and years of teaching experience are related to the criterion variable: the older, more experienced teachers did more poorly. Since age and experience are almost automatically positively correlated, we did whatever the data permitted to distinguish the effects of these two variables from each other. It is interesting that chronological age does not seem to be very important, but length of teaching experience does. This result suggests that even in the years of maturity under consideration, the unfolding years of a teacher's career, important intellectual changes may take place as a result of his work as a teacher. These changes may affect the teacher's amenability to education in new attitudes toward science. In the cases observed, longer years of high school teaching seem to have led to a more doctrinal approach toward science. The effects of teaching on the teachers are largely unexplored, but the present results suggest that these effects might provide valuable insights into the educational system as a whole. Under favorable circumstances, the teacher's career invites the growth of deeper and more flexible understanding of his subject; it is indeed unfortunate if our high school teachers now labor under conditions that produce the opposite effect.

One of the more puzzling features of our results is the negative correlation between time devoted to independent study and performance on the criterion variable. Previous research would have suggested a positive relationship. In particular, thesis work, or the actual conduct of scientific investigation, ought to increase the Fellow's concern for and grasp of ways of teaching about science as a way of thought. But, as shown in Table 17, Institute G, ranking second in time spend on independent study, ranked eighth on the criterion variable; and Institute C, ranking ninth on independent study, ranked first on the criterion variable. Much of the time spent on independent study can be ascribed to thesis work. Our information about the details of each program leaves something to be desired, but inspection of thesis topics suggests that most of them dealt with science education, rather than science proper. All that can be said at this time is that the nature of research experience is quite variable, and especially in a one-year training program, research topics must be chosen carefully if they are to contribute to awakening new attitudes toward science. Thesis research conducted in a spirit of routine fulfillment of a degree requirement, or research adjusted in subject matter and method to the needs of an ill-trained and hurried student, may simply consume time that might be better spent in other pursuits.

The results presented in this report suggest that, on a national scale, AYI programs may be relatively ineffective in influencing high school science teachers to teach science as a way of thought rather than as a set of established facts and doctrines. As pointed out previously (Gruber et. al., 1959) this should not be too surprising, since AYI adds only one year of education to the experience of a mature individual who has already had at least 16 years of formal education plus a number of years of professional experience. The AYI year must not only fill gaps in course work, it must undo well-entrenched misconceptions about science and build a fresh attitude toward the process of scientific inquiry. If we wish the year in AYI to have specific effects on the Fellows' attitude toward the fundamental character of science, it is only logical to plan a specific program with this end in view.

The hopeful feature of the results presented in this report lies in the fact that differences in educational programs do in fact produce differences in approaches to science teaching. What we need is an explicit program, deliberately designed to satisfy the Fellows' particular subject matter needs and at the same time develop an approach in which science is taught as a process of intellectual inquiry. It would be beyond the scope of this report to offer such a program. Bun in the past similar need have been felt and met, and means of meeting them experimentally tested. A recent example is Abercrombie's book, The Anatomy of Judgment, a British attempt to cope with the problem that "scientific ways of

thinking did not automatically result from learning the facts of science and that a more radical approach to training was necessary." (Abercrombie, 1960, p. 15). Working with medical students, Abercrombie developed a systematic but brief training program to forster scientific thinking about medical problems. The method was tested experimentally, with favorable results. Our own experiments, described above and elsewhere (see above ch. 1; also Gruber and Weitman, 1960; Weitman and Gruber, 1960; Hovey, Gruber, and Terrell, 1961), and those of other investigators make it clear that it is possible to take the seemingly intangible notion of "scientific way of thinking" and reformulate it as a set of recognizable and measurable cognitive skills, develop a training program to foster these skills, and finally, demonstrate experimentally whether or not the training program has the intended effects. The way is therefore clear to a more thoroughgoing attack on this problem. But does the will exist?

One last question deserves discussion, although we can offer only the most speculative suggestions for answering it: why do training programs stressing passive-receptive teaching methods foster the teaching of science as established knowledge while programs stressing active participation foster the teaching of science as a way of thought? Two somewhat different hypotheses suggest themselves. First, it may be that listening to lectues actually suppresses any embryonic tendencies to approach science as a process of intellectual inquiry. The listener, constantly striving to keep up with a highly trained, well-prepared lecturer must discipline himself not to think, otherwise he will lose the thread of the lecture and his notes will become a disorganized jumble of his own questions and ideas confused with the instructor's presentation. This might not affect the listener's general intellectual development if a lively discussion followed the lecture, but with students pursuing a busy schedule this is rarely the case. Secondly, the process of discussion is itself perhaps a form of thought similar to scientific inquiry. The main function of a lecture is usually the presentation of knowledge: the main function of a discussion is the exploration of ideas. The social dialogue begun in discussion is continued as an inner dialogue, or thought. In discussions of science, the prospective science teacher has the opportunity to try his own skill at formulating and reformulating the thinking that lies behind the formidable array of established knowledge. Without an abundance of such discussions he may never penetrate the facade of certainty to the arena of doubt in which intellectual inquiry unfolds.

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Appendix A

I. SAMPLE TEACHING OUTLINE

Sometimes in teaching it is a good idea to deviate from the usual progression of subjects in the syllabus. For example, a teacher may choose some topic in which he is personally interested. Often it is just such occasions, when the teacher lets himself go, that excite the students' interest in science or mathematics.

Instructions:

1. Choose some topic in science or mathematics that you know well and that interests you.
2. Prepare an outline for a twenty to thirty minute talk on this subject that would be appropriate for a group of high school seniors who have already had considerable work in science and mathematics.
3. Please make your outline clear enough so that another high school teacher in your field could understand the development of your talk.

You should take between twenty and thirty minutes to prepare your talk.

Write your finished outline on the blank pages that follow. . . . . .

Appendix B

DESCRIPTION OF TRAINING PROGRAM

We are interested in the relative importance that is assigned to a variety of objectives. We would like to have your impression of your present program as a whole, including courses, seminars, special lectures, projects, field trips, etc. In order to explore this question systematically, we are going to ask you to make certain estimates in a stepwise fashion. First, we will ask you to break down the time and energy (summarized as "percentage of the total effort") actually spent in your program into two broad categories. Then, we will ask you to take these percentages and further subdivide them in a more detailed way. When you have completed these two steps, we will ask you to repeat the same procedure as an expression of your conception of the ideal program. If there is any category where no effort is spent (or, in the second part, where you think no effort should be spent) on a given objective, use a zero to indicate this.

1. What percentage of the total effort in your present program has been devoted to each of the following objectives?

   _____ A. Increasing knowledge and skills in science and mathematics

   _____ B. Improving teaching techniques

   100% (Your total should add up to 100%)

2. Now place your percentages in the spaces provided in columns A and B (see spaces labeled "Your percentage"). Then within each column, subdivide your percentages among the four categories listed.

A. Percent effort on increasing knowledge and skills in		B. Percent effort on improving teaching techniques for
_____	standard subject matter	_____
_____	new developments	_____
_____	history & philosophy of science	_____
_____	the scientific method	_____
Totals should be _____	(your percentage)	_____

3. Now repeat the same procedure: this time your percentages should indicate your conception of the ideal program.

   _____ A. Increasing knowledge and skills in science and mathematics

   _____ B. Improving teaching techniques

   100% (Your total should add up to 100%)

   Again your percentages should be placed in the spaces provided in columns A and B (see spaces labelled "your percentage") and then subdivide within each column.

A. Percent effort on increasing knowledge and skills in		B. Percent effort on improving teaching techniques for
_____	standard subject matter	_____
_____	new developments	_____
_____	history & philosopy of science	_____
_____	The scientific method	_____
Totals should be _____	(your percentage)	_____